ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XVI, NR. 1, 2009, ISSN 1453 - 7397

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The Use of Spark Ignition Engine in Domestic Cogeneration

Cogeneration plants are strongly sustained by EU energy policies, one of the best beneficiary of this technology being residential buildings. This paper focus on spark ignition engine as a cogeneration application in order to supply energy for domestic consumers. Are considered two aspects of this solution: the energetic aspect and the environmental one. The energetic aspect deals with the energetic ratios, while the environmental aspect refers to the nitrogen oxide and carbon monoxide emissions.

Keywords: *spark ignition engine, cogeneration, load*

1. Introduction

A cogeneration system has to cover certain electrical and thermal loads reliably. As we continue to deplete natural resources and energy costs increase, building owners will facce increased pressure to improve plant efficiencies and performance. Cogeneration of heat and power (CHP) is a highly efficient mean of supplying heat and electricity. Also, this technique contributes to the preserving of resources and environmental protection.

In 1997 was held the United Nations Conference, which led to the publication of the Kyoto Protocol. In this respect, developed countries affirmed their intention to reduce their gas emissions with greenhouse effect. It is needed a major diminishing of the primary energy demand and also accelerating the replacement of the existing plants by new technologies with increased energetic efficiency. The efficient use of energy in CHP plants is one of the main ways of assuring the CO_2 emission reduction, goals laid down in the Kyoto Protocol.

CHP plants are strongly sustained by E.U., fact proven by the Directive on the Promotion of Cogeneration (Combined Heat and Power) based on Useful Heat Demand in the Internal Energy Market. In western E.U. countries are registered a lot of projects on cogeneration in buildings. The reason is that in this sector are needed, as we mentioned above, heat, electricity and sometimes cold. Results that in many cases either cogeneration or trigeneration plant can be set up as a main source of energy for buildings. We can affirm that residential buildings, but also hospitals, education establishments, commercial buildings or hotels, are the best cogeneration beneficiaries. Although this technology offers many technical and ecological advantages, the number of applications in some countries is poor enough in comparision to the need.

CHP dimensioning in domestic energy supply is related to object-related energy demands, general technical condition of the CHP integration and economic parameters. An optimal dimensioning of CHP units is possible by means of significant diurnal load curves. The dimensioning ought to be base-load oriented, in order to assure high annual utilization rates. It is better if the cogeneration system operates in parallel to the public grid and in heat-orientated operation mode. The general economic conditions and the different cogeneration dimensioning options have to be verified object-related in terms of economic efficiency.

In a domestic energy supply, is needed to be known diurnal and annual balance, given by the thermal and electrical energy demand (kWh), CHP production (kWh), additive delivery (kWh) and CHP surplus (kWh) and parameters and ratios of the SI engine.

2. Spark ignition engine as a cogeneration equipment

In the present, common used CHP power plant types are as following:

- steam turbine plants, e.g. back-pressure, extraction back-pressure, uncontrolled extraction type and extraction condensing turbine plants;
- gas turbine plants, e.g. with a waste heat boiler and, in some cases, an additional firing system;
- combined cycle gas turbine plants;
- internal combustion engine plants, e.g. gas or diesel engine plants;
- fuel cells, Stirling engines, steam engines.

Reciprocating internal combustion engines are a widespread and well-known technology. Spark ignition engines for power generation use natural gas as the favorite fuel, also being the possibility of using propane, gasoline or landfill gas.

The most simple reference cycle is Otto cycle which is composed of two isentropes and two isochors. This type of cycle is specific to spark ignition engines. For these engines the combustion is isochoric. Figure 1 show the Otto cycle.

Natural gas engines present low first cost, rapid start-up, good reliability when are properly maintained, excellent load-following characteristics and a high heat recovery potential.

Electric efficiencies of natural gas engines range from 28% LHV (for small stoichiometric engines, <100 kW) to over 40% LHV (for large burn engines, >3MW). Waste heat recovered from the hot engine exhaust and from the engine cooling system produces either hot water or low pressure steam for CHP technologies. Overall CHP plant efficiencies (electricity and useful thermal energy) of 70 to 80% are frequently obtained with natural gas engine systems.

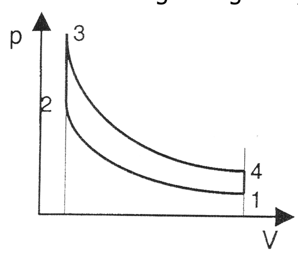

Figure 1. Otto cycle

3. Energetic and environmental assessment

The principal motivation of increasing the use of combined heat and power applications in domestic energy supply is given by their major contribution to an efficient and rational energy supply. Important aspects to characterize domestic energy supply by the spark ignition engine are the energetic and the environmental ones.

3.1. Energetic aspect

Table 1 shows technical parameters of the nominal load and energetic ratios of a CHP plant with a spark ignition engine.

Table 1. Technical parameters and energetic ratios of a CHP plant based on spark ignition engine.

electric load, kW		thermal load, kW		fuel power, kW	
Symbol	Value	Symbol	Value	Symbol	Value
P_{el}	16,8	P_{th}	37,4	P_f	54,8
exhaust gas temp, ^oC		heat yield, %		electricity yield, %	
Symbol	Value	Symbol	Value	Symbol	Value
t_e	67,9	α	68,3	β	30,7

This type of cogeneration system is a natural gas application, meaning that the fuel is the natural gas.

The thermal load of this technology specification is in connection with a return temperature of 50^{o}C in the downstream domestic heating system. In these conditions, the temperature of the exhaust gas in situated under the dew point. In this situation the energetic ratio, called heat yield, is of 68, 3% and the other energetic ratio realized, called electricity yield, is 30, 7%.

The energetic aspect is also given by the connection between the energetic ratios called relative yields and the level of load (see Table 2).

Table 2. Relative yields of a spark ignition engine in reliance with the load level.

Energetic ratio	level of load	0,5	0,75	1,00
relative heat yield, α/α_{max}	thermal load level	1	0,98	0,92
relative electricity yield $\beta/\ \beta_{max}$	electric load level	0,66	0,9	1

It is seen that best relative electricity yield is achieved for a full load or the range near full load operating state.

3.2. Environmental aspect

The natural gas is aquiring essential importance in the world in function of its abundance and environmental advantages. Replacing other fossil fuels, the natural gas leads to a decrease in the CO_2 emission. More over, in the environmental aspect, the natural gas takes advantage as for the local quality of the air, acid rains, attack to the layer of ozone, etc.

In Table 3 are given emission factors of greenhouse effects for the main fuels, including the natural gas [2].

Exhaust emissions are the primary environmental concern with natural gas SI engines. The primary pollutants are carbon monoxide (CO) and oxides of nitrogen (NO_x). Engines operating on natural gas which has been desulfurized in the refinery emit insignificant levels of SO_x.

Table 3. Emission factors of greenhouse effect gases for the main fuels

Fuels	Emission factors (t/TJ)			
	C	CO	CH_4	NO_x
Fuel oil	21,10	0,015	0,003	0,161
Diesel oil	21,81	0,990	0,220	0,990
Natural gas	15,30	0,017	0,002	0,067
Firewood	0,00	0,002	0,015	0,115
Coal	26,80	0,093	0,002	0,329
Sugar cane bagasse	0,00	0,002	-	0,088

In Table 4 are given values of CO and NO_x emission components, registered during part and full load operating state.

Table 4. CO and NO_x emissions for 50% P_{max} and 100% P_{max}.

P_{max}	50%	100%
CO/CO_{max}	100%	25%
$NO_x/NO_{x\ max}$	30%	100%

A higher CO emission rate is seen during the part load because of an incomplete combustion of the natural gas. NO_x emission is assessed from the excess air and the nitrogen content in the fuel, generally in operating state. Nitrogen oxides emissions are usually the primary concern with natural gas engines. This component is responsible of large changes in a surrounding environment. NO_x leads to acid rains and smog formation and also has a direct negative impact on human beings.

4. Conclusion

The paper reveals the implications of using CHP power plants based on spark ignition engines in domestic cogeneration, being known the fact that this technology shows many technical and ecological advantages. Despite of this, the number of applications in some countries is not at the level of the need.

The assessment of this technology focused on the energetic and environmental aspects. Are given energetic ratios like the heat yield (68, 3%) and the electricity yield (30, 7%), but also relative yields depending on the load level. It is seen that the best relative yields is obtained for a level of load of 50%, and the best relative electricity yield is achieved for a level of load of 100%.

This type of cogeneration system being a natural gas application, the primary environmental concern refers to CO and NO_x pollutants. The higher CO emission rate is seen during the part load. NO_x emissions are usually the most important concern with natural gas engines.

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